

**DESIGN AND FABRICATION OF A SOLAR-POWERED TRICYCLE UTILIZING AN
AC MOTOR FOR SUSTAINABLE URBAN MOBILITY**



BY

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BENIN CITY.

FEBRUARY 2025.

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**A PROJECT SUBMITTED IN PARTIAL FULFILLMENT FOR THE REQUIREMENT
FOR THE AWARD OF THE BACHELOR OF ENGINEERING (B.ENG) DEGREE.**

IN

AGRICULTURAL ENGINEERING PROGRAMME

DEPARTMENT OF PRODUCTION ENGINEERING

FACULTY OF ENGINEERING.

UNIVERSITY OF BENIN, BENIN CITY, NIGERIA

FEBRUARY 2025.

CERTIFICATION

We, the undersigned, certify that this work was carried out by **ONWUKA GODBLESS UGOCHUKWU** in the Department of Production Engineering, Faculty of Engineering, University of Benin, Benin City. For the requirements of the award of Bachelor of Engineering (B.ENG.) Degree in Agricultural Engineering

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DEDICATION

I dedicate this project work to God Almighty for being my strength and help. Indeed, by God, I have run over a troop, and I have leaped over a wall.

ACKNOWLEDGEMENT

To God Almighty, your divine grace and unwavering presence in my life have been a constant source of strength and inspiration. I am profoundly thankful for the blessings, wisdom, and inner strength You have provided, guiding me through this great journey.

To the Head of Department (HOD), Prof. Patrick Ejobheare Amialemhen, your exemplary leadership, unwavering encouragement, and steadfast commitment to academic excellence have profoundly shaped my academic and research journey. Thank you for all you do for every student in the department, and for being a father figure.

I extend my sincere appreciation to my supervisor, Dr. R.S. Ebhojiaye, for his invaluable mentorship, patience, and expertise. Your guidance has been instrumental in refining my research skills and shaping the direction of this project. Your dedication to my success has been a driving force behind these achievements.

A big shout-out to my parents, Mr. & Mrs. Onwuka; my siblings and my extended family for their significant financial contributions, unwavering love, encouragement, and prayers throughout this journey. God bless you all; I love you all.

A big thank you to everyone who prayed for me and supported me financially throughout this phase. God bless and increase you all.

I will also not fail to appreciate my course-mates, senior colleagues, and my dear friend for their immense support and encouragement God bless you.

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ABSTRACT

This project focuses on creating an eco-friendly and energy-efficient transportation option for urban areas. The main objective is to develop a solar-powered tricycle that leverages renewable energy to lower the carbon emissions typically associated with traditional urban transport. The tricycle is equipped with a high-efficiency AC motor powered by energy collected from a solar panel system on the vehicle. The design prioritizes optimal energy use, enhanced efficiency, and the capability to meet urban commuting demands.

Key elements of the project include a solar panel array, a power distribution controller for effective energy management, and a durable battery storage system for energy reserves. The AC motor is chosen for its reliability and effective performance at low speeds, providing a smooth and stable ride. Furthermore, the tricycle features a lightweight and user-friendly design to improve comfort and maneuverability in busy urban environments.

This initiative presents a novel solution for sustainable urban mobility, serving as a clean alternative to conventional vehicles. It seeks to help mitigate air pollution, reduce reliance on fossil fuels, and encourage the integration of solar energy in transportation. The final tricycle will exemplify the feasibility of solar-powered mobility options in contemporary cities, marking a significant advancement toward green and sustainable urban transportation.

CHAPTER ONE

INTRODUCTION

1.1. Background to the Study

The environment has been facing significant challenges in recent times, leading to detrimental effects on both people and the planet. The ozone layer plays a crucial role in protecting life on Earth from harmful solar radiation, making it vital for the safety of our planet and the survival of all living beings. With the global population on the rise, there is an increasing need for energy solutions that are both sustainable and beneficial to health. Renewable energy, sourced from naturally replenishing and environmentally friendly origins, has become a promising alternative. There are various types of renewable energy such as solar, wind, hydropower, geothermal, and biomass energy.

In contrast, non-renewable energy sources are limited and often linked to environmental issues like pollution and greenhouse gas (GHG) emissions. According to the most recent data, CO₂ emissions are the major global contributors to GHG emissions, accounting for 74.4% of total GHG emissions, followed by CH₄ and N₂O, which accounted for 17.3% and 6.2%, respectively, of total GHG emissions (Journal of cleaner production 2024). As a result, renewable energy is gaining popularity for its positive impact on the long-term health of the Earth and its inhabitants. By 2021, renewable energy sources had helped prevent approximately 2.6 billion metric tons of CO₂ emissions globally each year, making them a more favored choice compared to non-renewable sources (Jesuleye et al., 2008).

Since the Industrial Revolution, energy consumption has surged dramatically. This increase is driven by both individual energy use and population growth. However, this trend can be addressed through the widespread production of photovoltaic (PV) cells, which efficiently convert solar energy into electricity with minimal fluctuations. This technology can power electric vehicles, alleviating pressure on the energy sector and fostering a more sustainable

environment. Solar-powered vehicles (SPVs) present a viable solution for cutting down CO₂ emissions and creating a cleaner environment. The energy systems needed for SPVs will heavily depend on renewable sources, particularly solar photovoltaic power, as seen in solar-assisted tricycles (Kandasamy et al., 2013).

Although solar energy is known for its performance and efficiency, the main challenge has been the scarcity of resources. However, Nigeria is blessed with abundant solar energy resources, yet the most popular mode of transportation in urban areas is internal combustion engine (ICE) vehicles, which contribute to carbon emissions. Human activities that increase global carbon emissions are the primary cause of climate change and global warming. Therefore, to reduce carbon emissions and promote sustainability, the project aims to design a prototype solar-powered tricycle as an alternative mode of transportation.

The basic working principle of a solar-powered tricycle is to provide motive force to a shaft by an electric motor, which runs on solar energy after some important conversion. This is done instead of using an internal combustion engine (ICE), which produces environmental pollution. The electricity produced by photovoltaic (PV) cells using the energy from the solar system (sunlight) directly powers the electric motor for driving the solar-powered tricycle (SPTs). During sunlight hours, the electricity is produced by the PV cells. Otherwise, the tricycle use energy from their batteries.

There are different types of tricycles, they can be classified as paddle tricycles, internal combustion engine tricycles, and electric tricycles. Paddle tricycles require a lot of energy to paddle the tricycle, which can make the user tired. For instance a worker, being resourceful becomes challenging after pedaling a paddle tricycle to reach their work place. Next, the internal combustion engine (ICE) tricycle is mostly powered by fuel or gas, which is costly and produces a bad impact on the environment by warming the earth. Lastly, the electric tricycle is battery-powered, running on solar energy. For those dreaming of a healthy city, the electric

tricycle is the best among the three cycles. They are cost effective, emit fewer fumes, allowing city dwellers to work without getting sweaty and reducing waste.

The solar-powered tricycle, in particular, is designed to be driven by a pair of AC motor that is fitted in the rear axle housing. The tricycle is powered by solar energy, which is harnessed through solar panels mounted on the roof. The solar panels charge the battery, which then drives the hub motor. This technology is an innovative and sustainable solution that reduces the reliance on fossil fuels, thereby contributing to a greener and cleaner environment.

1.2 Statement of the Problem

In contemporary Nigeria, the transportation sector is grappling with several challenges, such as cost and environmental concerns, particularly those related to environmental concerns. One major issue is the prevalence of carbon emissions, which have a significant impact on environmental pollution and climate change. The dependency on fossil fuels in the country's transportation sector is of particular concern, given their association with carbon emissions. The widespread use of fossil fuel vehicles in urban areas has led to an alarming increase in carbon emissions that negatively affect the environment. (Jesuleye *et al.*, 2008)

Moreover, the transportation of goods and people on farms and farmsteads is a significant challenge. The availability of environmentally friendly, efficient, and safe transportation in such settings is limited. The use of carbon-emitting vehicles in farmsteads is hazardous to the farm environment, and alternative solutions are required. The use of renewable energy sources as fuel for transportation is a viable solution to this challenge.

Lastly, transportation costs remain high in Nigeria, mainly due to the high cost of fuel. The high transportation costs disproportionately affect low-income individuals living in urban areas, making it challenging for them to afford transportation. Solar-powered tricycles present a cost-effective transportation solution that can promote sustainable development in the transportation sector. In light of rising fuel prices, solar-powered tricycles offer a more

affordable and sustainable mode of transportation that can help alleviate the transportation challenges faced by low-income individuals in urban areas.

1.3 Aim and Objectives of the Study

The aim of the study is to design and fabricate the chassis of a solar powered four-passenger seater tricycle using locally sourced materials, and to also install all electrical components needed to power the tricycle.

The Objectives of the study are to:

- i. To design a solar PV system-powered tricycle prototype to utilize solar energy as a renewable energy resource.
- ii. To fabricate the tricycle and complete it with an off-grid solar PV charging system; and
- iii. To evaluate the structural integrity of the tricycle chassis.

1.4 Scope of the Study

This paper centers on the design calculations and analytical computations related to different components within the photovoltaic system, electrical system and the mechanical system of the tricycle, including: Solar panel, Charge controllers, Inverter, Batteries, Electric Motor, Chassis/Frame, Braking System, clutch system and Steering System.

Our goal involves assessing the structural designs, stability, credibility, rating, and longevity of these components to attain optimal efficiency over a prolonged period. The study underscores the importance of user-friendliness and high efficiency during the design process.

1.5 Limitations to the Study

The study's constraints encompass the following aspects:

- i. The amount of energy that can be generated by the solar panels: The size and efficiency of the solar panels determines the amount of energy that can be harnessed, and this may

not be enough to power the tricycle continuously, especially in areas with limited sunlight.

- ii. The weight of the tricycle: Adding solar panels and a battery can increase the weight of the tricycle, which can affect its speed, maneuverability, and overall performance.
- iii. The cost of the solar panels and battery: While the long-term savings on fuel costs may make up for the initial investment, the upfront cost can be a barrier for many consumers. Manufacturers need to find ways to make solar powered tricycles more affordable and accessible to a wider consumer.

1.6 Significance of the Project

Solar-powered tricycles offer a sustainable and cost-effective solution to transportation in today's era of increasing environmental concerns and energy crises. With the integration of solar power, tricycles can run on a clean and abundant source of energy. The tricycles are equipped with solar panels that absorb sunlight, convert it into electrical energy, and store it in a battery. This stored energy powers the tricycle's motor, providing a smooth and efficient ride.

The importance of solar-powered tricycles lies in their ability to reduce carbon emissions and dependence on fossil fuels. As countries strive to reduce their carbon footprint, solar-powered vehicles become increasingly important. Solar-powered tricycles have the potential to significantly reduce carbon emissions and combat climate change. Furthermore, solar energy is a free and renewable resource, making the cost of operating a solar-powered tricycle significantly lower than a traditional gas-powered vehicle.

The use of solar-powered tricycles can also have significant benefits in agriculture. Farmers can use these tricycles to transport their produce and equipment from one location to another, without adding to the carbon footprint. The solar-powered tricycles can also be used to power farm tools and equipment, reducing the need for expensive and polluting gasoline-powered machinery.

Using a tricycle instead of a traditional car can also reduce traffic congestion and promote physical activity. Tricycles are smaller in size, making them easier to maneuver through congested urban areas. Additionally, tricycles provide low-impact exercise, which can improve cardiovascular health and overall well-being.

Overall, the design and fabrication of solar-powered tricycles can make a positive impact on the environment and individual well-being. Solar-powered tricycles reduce carbon emissions, promote sustainability, and encourage physical activity. Thus, the design and fabrication of solar-powered tricycles should be encouraged and supported as a means of promoting sustainable and healthy transportation options.

CHAPTER TWO

LITERATURE REVIEW

The Solar-powered tricycle is a three-wheeled vehicle that can be powered by solar energy. It has a solar panel, a charge controller, a battery, a Variable frequency drive (VFD), a motor controller and two AC motor as its components. It uses solar radiation in two forms to generate energy: electricity generated by the solar cells that are excited by the semiconductor on the PV cell and heat accumulated by the solar collectors.

According to Adhisuwignjo *et al.* (2017), the solar cells in the tricycle work on the principle of the photovoltaic effect, which creates a potential difference due to electromagnetic radiation at the junction of two different materials. A battery is used to convert chemical energy into electrical energy. A rechargeable battery can store and discharge energy many times, while a non-rechargeable or primary battery is fully charged and then discarded when it is discharged.

The charging action of the battery occurs when the positive, active material is converted to oxidizing and the negative material consumes electrons. The electrolyte is supplied as a buffer for electron flow between the electrodes. The current flow in the external circuit is operated by constituent electrons. The charger controller is responsible for controlling the charger that goes into the battery for the Photovoltaic cell, (solar panel). The Inverter converts the Direct current(DC) from the battery to Alternating current(AC) which is then supplied to the electric AC motor using cables. The AC motor consist of various components and its main parts are the stator, rotor and shaft. An AC voltage is supplied to the stator windings and then generate an alternating magnetic field, The interaction of the magnetic fields produces torque, which is the rotational force that drives the rotor.

The present solar-powered tricycle in the market is equipped with a weighty chassis/frame and oversized wheels. To accomplish required weight reduction, the design incorporates smaller wheels. However, the design does not compromise the requisite strength of the tricycle. To

achieve this, the chassis is constructed with steel pipes reinforced with angle bars wherever necessary. This design ensures it can withstand essential loads and absorb any shocks (Apostolou *et al.*, 2018).

The size and overall state of the nation's roads, including any bumps, potholes, etc., are carefully taken into account while selecting wheels. Each solar-powered tricycle has an equal diameter. Better traffic ability is achieved by using all-terrain tires. Pipes, steel sheets that are as thin as possible and are used to make up the solar-powered tricycle's body in order to reduce weight while maximizing strength. The chassis is connected to a waterproof, padded seat that may be adjusted. With a panel mounting frame composed of light steel angle bar welded to the main frame/chassis, the solar panel is positioned on roof (above).

Here, steering is accomplished by attaching a standard handle bar to the front wheel, adorned with switches, brake levers, and accelerators, among other things. An accelerator that continuously modifies voltage via a twist throttle governs the speed of the solar-powered tricycle. By altering the voltage, one may regulate the speed because variations in voltage also affect motor power.

2.1 Analysis of Relevant Literature

A literature review involves evaluating prior work by various authors, gathering information from research papers in journals to advance a specific task. It serves as a means to discover fresh ideas and concept, drawing from previously published literature on similar task with diverse approaches.

Asrori *et al.* (2020) compared PWM and MPPT of the Charging Controller from the flexible solar panels to work optimally as a battery charging system on electric tricycles. The results showed that the PWM Solar charger can produce the average power output of 29.92 Watt, while the MPPT type is 38.89 Watts.

Apostolou *et al.* (2018) designed a tricycle equipped with electric motors that can be powered by pedal or by solar PV charging on electric motor supply. Solar-powered e-bikes are concluded to have potential as a sustainable way of transportation in urban areas and cities.

Adhisuwignjo *et al.* (2017) constructed an electric tricycle battery charging system with solar energy sources using fuzzy logic algorithms. Fuzzy logic controllers can keep the battery charging current in solar-powered electric tricycles to remain stable.

Mishra *et al.* (2016) designed a solar hybrid tricycle consisting of the following components: hub motor, solar panel, lead acid battery, motor controller, accelerator, bicycle & dynamo. Hybrid tricycles combine the use of solar energy as well as the dynamo that successfully runs through the pedal to charge the battery to run the tricycle.

Kandasamy *et al.* (2013) constructed a tricycle powered by solar energy. The main component of the tricycle is Solar PV panel, Brushless PMDC motor, Charge controller and battery. The tricycle is successfully effective in providing mobility for persons who have disabilities.

Christu Jyothi Institute of Technology & Science (CJITS), Jangaon (2010) invented a solar tricycle which was made with a 40W solar panel, motor and mechanical gears.

University of Engineering and Technology, Lahore, Pakistan (2011), an electric reverse tricycle (two wheels at the front and one at the back) for one person was invented which is powered by solar energy.

Woodbridge School in California (2008) stimulated a solar-powered tricycle, which was energized by a 600-watt motor and it sped up to 17mph.

General Motors Powerama (2012) designed a solar powered automobile (Sunmobile), but due to its small size, the Sunmobile could not be driven by human.

In India (2012), A hybrid solar car was introduced which consists of internal combustion engine (ICE) and solar panel, electric motor powered by storing battery system energized by a solar panel. Also a study about the design and feasibility of solar powered bicycle had given where the 250W motor and 2 solar panels of 20W were used and maximum speed 25 km/h was found.

A group of PEC Mechanical Engineers (2013) invented a SPV. Three batteries and a 250 watt motor inside the vehicle were used. The motor, which weighs approximately 5kg, gets its power from solar energy. This vehicle can reach speeds up to 15kmph.

Woodbridge School in California (2009) constructed a solar powered vehicle (SPV) having a 100W solar panel, 750W DC Motor, and mechanical gears.

In India (2014), a solar tricycle, especially for a handicapped person, was constructed by a 250-watt motor, the three-wheeler can reach speeds of up to 33 km/h and load carrying capacity is 90 kg.

Team Solar Panel (2014), a solar powered vehicle was constructed where 850 W motor, 4 batteries and 4 solar panels of 100W was used. Its average speed was 15-20 km/h.

(Jesuleye *et al.*, 2008; Adejumobi *et al.*, 2011) proposed the inverter system plays a crucial role in the national energy mix, especially considering the challenges posed by global fossils fuel costs and the impracticality of relying solely on generators in remote areas, which are constrained by limited running hours and rising fuel costs.

Ezugwu (2012) emphasizes that solar power has the capability to convert absorbed solar energy, storing it in a lead-acid cell for subsequent use. In regions with ineffective power supply, the utilization of solar power proves immensely valuable, especially in areas blessed with abundant sunlight and high temperatures, which are crucial for fueling solar power supply units. Solar power is cost-effective when compared to alternative power sources like generators

relying on fuel or diesel. The longevity and reliability of solar power devices are enhanced when operated within or above their specified ratings.

In Pakistan (2014), a scooter made of 350 W DC hub motor and 4 solar cells for charging the 48V/20AH battery was invented.

Jianget *al.*(2005) introduced the concept of "Maximum Power Tracking for Photovoltaic Power Systems." The paper outlines an efficient design for a Photovoltaic (PV) model, focusing on effectively tracking the maximum power operating point. This emphasis aims to overcome the oscillation issues associated with the commonly used Perturbation and Observation (P&O) algorithm, which is employed for low-cost control array to track the maximum power point. The study introduces the three-point weight point comparison method as an alternative to address the oscillation problem inherent in the traditional P&O algorithm.

Penget *al.* (2005) introduced the concept of a Z-Source Inverter for Motor Drives in this study. The paper advocates for the use of a Z-Source Inverter in conjunction with a motor drive system. In this distinctive network, an LC network is employed, and the DC source along with the front-end diode bridge rectifiers is connected to the inverter. The Z-Source Inverter produces the desired AC output, controlled by the shoot-through duty cycle, resulting in an output voltage greater than the line voltage. This innovative impedance source inverter system offers ride-through capability during voltage sags, diminishes harmonics, improves power factor correction, and enhances reliability, while also increasing the output voltage gain. Similar to its counterpart, the Z-Source Inverter-based Adjustable Speed Drive (ASD) operation finds application in various scenarios.

Jean Pierre Twajamahoro. *et al.*(2018) made research on "Tricycle powered by Solar Energy". The paper gave the details related to tricycle project and includes the methods and consideration regarding the proper working principle of tricycle powered solar energy. The research includes all the information regarding the solar powered tricycle for handicapped persons and its

components used on it. The paper emphasized that transportation is inseparable part of human life. It also gave the essence of green and pollution-free transportation.

2.2. Main Parts of the Solar Powered Tricycle

The solar powering system of the tricycle consists of:

- i. Solar Array which collects solar energy and convert it to electrical energy
- ii. Power trackers (charger controller) to achieve the proper voltage to be stored in batteries.
- iii. Batteries to store power.
- iv. Current inverter (variable frequency drive) to convert current from DC to AC
- v. Motor controller which adjusts the power input to the motor.
- vi. An electric motor which drives the vehicle.

This solar powered tricycle is composed by: Chassis/Frame, Wheels, Body, Seat, Solar panel mounting frame, Solar Panel, Charge controller, Battery, AC Motor, Steering System, Speed Controller, Brake System, lights etc.

2.2.1. Chassis/Frame

The frame and chassis weighs precisely the proper amount, and its wheels are of a modest size. Therefore, extra weight was cut during design in order to satisfy the criteria. When necessary, angle bars were used to reinforce the steel pipes used in the design of the three-wheeler chassis. The chassis was built to both absorb shocks and resist required loads. There were also some overall length and breadth reduction.



Fig. 2.1: Chassis of the tricycle

2.2.2. Wheels of the Tricycle

The size and general state of the nation's roads, including any bumps, potholes, etc., will be carefully taken into account when selecting the wheel. Each of the three wheels will have the same diameter and be of the same size. For improved traffic ability, all-terrain tires are utilized.

2.2.3. Body and Seat of the Tricycle

The solar three-wheeler's body is constructed of pipes. The chassis is coupled to a waterproof, padded seat that may be adjusted.

2.2.4. Solar Panel

The solar panel will be set on the top (over head) with panel mounting frame made of light steel pipes duly attached to the main frame/chassis.

2.2.5. Charge Controller

To get the most power out of the solar panel throughout the day, a solar charge controller will be selected for the solar three-wheeler's solar power system. Microprocessors will be in charge of this, monitoring and logging the panel voltage and current on a regular basis so that the power output may be calculated and adjusted. In order to securely charge the lead-acid battery, this solar charge controller will take the variable voltage from the solar panel and condition it.

When the lead acid batteries are almost empty, it will disconnect the batteries from the load to avoid damaging them. It will also shield the panels from the batteries after the sun sets. Here, a 12-volt lead-acid battery will be charged using the energy gathered from solar panels. It will have an LED bar readout to display the batteries' and solar charging system's current conditions. Compared to a typical charge controller, around 20 to 30% more energy may be produced with the aid of this solar charge controller.

2.2.6. Battery, Motor of the Tricycle

This solar three-wheeler will employ a AC induction motor as its prime mover. This motor is primarily used because of its high efficiency and constant flux density throughout time. Its performance attributes are highly suitable for our solar three-wheeler's needs.

2.2.7. Steering System and Brake System

For increased safety, this solar three-wheeler's front and rear left wheels will both use regenerative braking. The brake is engaged using the hand lever that is connected to the handle and steering. Here, the steering will be provided by a standard handle bar that is coupled to the front wheel and embellished with switches, brake levers, and accelerators, among other things.



Fig. 2.2: Steering wheel

2.2.8. Speed Controller of the Tricycle

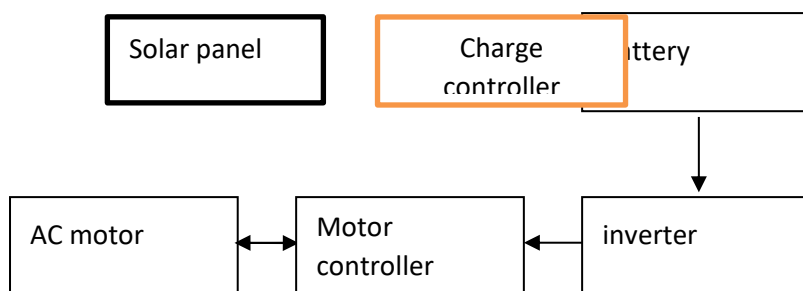
The speed of the solar three-wheeler will be controlled by an accelerator through continuous change in voltage by a twist throttle. Due to voltage change the motor power also changes and thereby speed is controlled by increasing or decreasing the voltage.

A standard solar power system consists of a solar panel (photovoltaic or PV panels), a charge controller, and a power inverter equipped with a meter or monitoring system to oversee voltages, system conditions, and the electrical distribution network.

2.4. Solar Power System

The primary source of earth's energy is solar power, derived from the sun's constant supply of delightful heat and radiation. Electricity generated from sunlight does not deplete natural resources, providing earth with continuous energy. In the tropical zone, Gupta found that solar energy reaching the earth is approximately 1 kilowatt per square meter daily. In experiments by the US Department of Energy, photovoltaic cells, also known as solar cells, were observed converting sunlight directly into electricity. When sunlight hits these cells, it dislodges electrons, creating an electron imbalance between the treated front surface and the back, allowing current to flow through a connector. (Ezugwu 2012)

The following definitions explain some key concepts related to solar geometry and the characteristics of solar radiation availability:



2.4.1. Solar Constant

The quantity of heat from the sun that travels an average distance to reach the earth's surface is known as the solar constant. The solar constant has been calculated differently by several experts. Suggested by C.G. Abbott in 1913, the most typical figure for 40 years was 1357 W/m², with a variance of 1.80%. (Duffie and Beckmann, 1991).

2.4.2. Solar Declination

This is the angle that results from projecting the line connecting the sun's center and the earth's center onto the equator's plane. In the summer months in the Northern Hemisphere, declination is positive when it is north of the equator and negative when it is south of it. (Duffie and Beckman, 1991).

The angle formed by the Sun and the equator of the Earth is called the solar declination. On the winter solstice, it is -23.45 degrees, and on the summer solstice, it is +23.45 degrees. In engineering calculations, daily variations in solar declination can be taken for granted. The average days of each month are displayed in the table below, along with the corresponding day of the year (n) for each month. (Duffie and Beckmann 1991).

2.4.3. Incidence angle

A line perpendicular to a surface is called its normal. The deviation of the sun's rays from this normal is known as the solar incidence angle, or θ . The angle of incidence (θ) and angle from the zenith (the point directly above) (θ_z) are equal if the surface is horizontal. (Duffie and Beckman, 1991)

2.4.4. Hour angle

The hour angle is the degree to which the sun is positioned with respect to the local meridian. It is dependent upon the earth's rotational speed, which is 15° revolutions per hour. When the sun is at its greatest point in the sky, the hour angle is zero and varies by 15 degrees every hour

after that. For example, the hour angle at 7am (solar time) is -75 degrees. This indicates that it is five hours before noon, and the negative sign denotes morning (Duffie and Beckman, 1991).

2.4.5. Solar radiation at the earth surface

The atmosphere affects the solar radiation that reaches the earth's surface by reducing the direct radiation through scattering and absorption by air molecules, dust, water vapor and ozone. The total solar energy that arrives at the earth's surface is composed of direct and diffuse components. The intensity of solar radiation depends on factors such as season, latitude, altitude, cloudiness and orientation of the surface that receives it (Duffie and Beckman, 1991).

2.5. Advantages of Solar-Powered Tricycles

Solar-powered tricycles offer a wide range of advantages that make them an excellent option for environmentally conscious individuals, small business owners, and those looking for a cost-effective and reliable mode of transportation. Firstly, solar-powered tricycles are eco-friendly and emit zero emissions, unlike gasoline-powered vehicles that emit harmful pollutants that contribute to air pollution and climate change (Masud *et.al.* 2017). The use of renewable solar energy also helps to reduce the dependence on fossil fuels and promotes sustainable living.

Secondly, solar-powered tricycles are cost-effective and require minimal maintenance. They do not require gasoline or other fuels, and there are no regular oil changes or tune-ups required. Solar-powered tricycles have fewer components than traditional vehicles, which makes them easy to repair and maintain (Twajamahoro*et.al.* 2018). This means that the overall cost of ownership is significantly lower than traditional vehicles, making them a popular choice for individuals and small businesses with limited budgets.

Thirdly, solar-powered tricycles are ideal for short commutes, deliveries, and transportation services in areas where public transportation is limited or unavailable. They are easy to maneuver in tight spaces, making them ideal for navigating through busy urban areas with

heavy traffic. Solar-powered tricycles are also lightweight and compact, which means that they can easily access areas that are inaccessible to conventional vehicles.

Finally, solar-powered tricycles can be a source of income for individuals who use them for commercial purposes, such as food delivery or transportation services. They are perfect for small business owners who need a reliable and cost-effective mode of transportation for their products or services. The flexibility and versatility of solar-powered tricycles make them an excellent investment for anyone looking for an eco-friendly, cost-effective, and reliable mode of transportation.

2.6. Disadvantages of Solar-Powered Tricycles

While solar-powered tricycles offer numerous advantages, there are also some disadvantages such as the initial high installation cost, dependency on sunlight, intermittency due to weather conditions. Energy storage solutions can mitigate some issues, but they add extra costs (Apostolou *et al.* 2018).

The performance of a solar-powered tricycle can be affected by weather conditions, as solar panels require direct sunlight to function at optimal efficiency. This means that on cloudy or rainy days, the tricycle may not be able to travel as far or as fast.

Also, solar-powered tricycles may not be suitable for long-distance travel, as the battery life can be limited. While advancements in battery technology have improved the range of solar-powered vehicles, they still may not be able to travel as far as conventional vehicles without requiring a recharge.

Furthermore, solar-powered tricycles may not be as fast as conventional vehicles, as they typically have lower maximum speeds. This can make them unsuitable for certain types of transportation services or deliveries that require a faster mode of transportation.

Finally, solar-powered tricycles may not be as widely available or supported as conventional vehicles. This means that finding replacement parts or repair services for solar-powered tricycles can be challenging, especially in areas where they are not as common.

2.7. Areas of Application of Solar-Powered Tricycles

Solar-powered Tricycles find applications in various areas, including:

- i. Rural transportation: Solar-powered tricycles can be used for transportation in rural areas where there is little or no access to public transportation. They can be used to transport people, goods, and farm produce.
- ii. Urban commuting: Solar-powered tricycles can be used for short commutes in urban areas. They can be an ideal alternative to cars, especially for short distances, and can help reduce traffic congestion and air pollution.
- iii. Tourist transportation: Solar-powered tricycles can be used to provide eco-friendly tours in areas where gasoline-powered vehicles are restricted. They can be equipped with audio guides and other features to enhance the tourist experience.
- iv. Waste collection: Solar-powered tricycles can be used for collecting waste in urban areas where larger collection vehicles are not feasible. They can be equipped with waste bins and can help reduce noise pollution from traditional waste collection vehicles.
- v. Security patrol: Solar-powered tricycles can be used for security patrols in urban areas. They can be equipped with cameras and other features to help ensure public safety.

CHAPTER THREE

METHODOLOGY

3.1. Material Selection Technique

The choice of materials was influenced by a number of factors, such as the kind and degree of stress that the components would experience, their rigidity or flexibility, their exposure to high temperatures or corrosive environments, and how these factors would affect the manufacturing processes (such as machining and forging). Moreover, weight was considered. Because the weight of the tricycle's parts and the power source (a solar panel) determined how much power the AC motor needed, we made sure to use lightweight, high-strength materials when fabricating it. The following elements therefore affected the choice of material:

- vii. Strength
- viii. Availability and cost
- ix. Weight
- x. Appearance
- xi. Machinability
- xii. Resistance to wear or corrosion
- xiii. Cost of Production

These will also determine the variation between success and failure of the machine. We can further classify the above factor into four main classes:

1. Service Requirements
2. Construction Requirements
3. Economic Requirements
4. Maintenance Requirements.

3.1.1. Service Requirements

Prior to being used in building, a material must have certain unique qualities that it displays when used. Generally speaking, these characteristics are known as the service demand. Among these qualities that ought to be noticeable while the material is in use are

- i. Toughness
- ii. Hardness
- iii. Strength
- iv. Stiffness
- v. Resistance to corrosion
- vi. Conductivity and heat resistance

3.1.2. Fabrication Requirement

The main qualities that a material must possess in order to be manufactured are malleability, ductility, weldability, and forgeability. It is possible to mould a material into the required shape by heating it to a temperature close to its melting point. For ductility, the material must be drawn into a wire form, and for malleability, it must be moulded into a sheet-like shape. The ability of the material to be easily welded may ultimately be called weldability. Therefore, attaching the materials must be possible through welding.

3.1.3. Economic Requirement

This is arguably the most important consideration when choosing materials since it has an impact on the whole cost of production, which in turn affects retail prices, customer preference, and product pricing. The end product is likely to be high if the total cost of production is high, and consumers will seek out less expensive options when a product is pricey. Profit maximisation and meeting customer demands and desires are the two main objectives of

production. One must carefully select reasonably priced, dependable, and job-appropriate materials as a producer. It will be less expensive than other similar materials as a result of the production's overhead expenses being reduced. At that point, it will be easy to balance the production cost against the actual price. Creating dependable, affordable, and capable machines that can solve problems for people is a top priority when designing an engineering system. We took this into account when working on this project.

3.1.4. Machine Components of the Tricycle

These are unit components that are assembled together to form the entire tricycle. The machine components include: the tricycle structural frame, chassis, steering system, brake system, solar system, AC motor, pulleys, belt, shaft, bearings, and wheels.

3.1.5. List of Materials Used

List of Materials used in the fabrication of the Solar Powered Tricycle:

- i. Solar Panel.
- ii. Lead-Acid battery.
- iii. Charge Controller.
- iv. AC Motor.
- v. Braking System (Speed Controller).
- vi. Wheel.
- vii. Cable Wires.
- viii. Mild Steel Frame.
- ix. Metal Sheet.
- x. Electrode.
- xi. Angle Bars.
- xii. Shock Absorber.

3.5.2 Solar Panel

A solar panel is an apparatus that harnesses solar radiation and transforms it into electrical energy. The solar panels are composed of silicon crystals that generate direct current (DC) electricity by absorbing sunlight. Batteries can store this energy for later use, or electrical equipment can use it directly. An inverter is used to change the solar panels' DC electricity into alternating current (AC) electricity. Using multiplier modules in addition to the typical solar panel unit can boost the amount of energy generated. This can be quite useful on cloudy or rainy days when there is little sunlight. Batteries can be used to store the excess energy, guaranteeing a steady supply of electricity (Adejumobi et al., 2011).

The system design will determine whether the panels are connected in parallel or series. Series wiring raises the system's voltage, whereas parallel wiring raises the amperage. The particular requirements of the system can also affect the panels' size, voltage, and amperage. All things considered, solar energy is a dependable and sustainable resource that may be applied in a number of contexts.



Fig. 3.1: 450W Solar Panel

3.1.6 Solar Batteries (Lead Acid Battery)

Commonly used in solar systems, sealed lead-acid batteries are the preferred choice for grid-connected systems due to their spill-proof nature and lack of maintenance requirements. Flooded lead acid batteries are less expensive, but they need distilled water added at least once a month to replace the water lost during regular charging.

Lead acid batteries come in two varieties: gel cells and sealed absorbent glass mats (AGM). AGM batteries have dominated the market because they don't need to be maintained, and they work especially well in grid-tied systems that need to be charged continuously. It is generally not recommended to overcharge gel-cell batteries, which are designed to survive freezing temperatures, as this can result in irreparable damage. The rated capacity of lead acid batteries are typically stated in terms of C/8, C/10, and /20 hour rates. While UPS batteries are rated for 8 hours, telecommunication batteries are rated for 1-0 hours, with 12VDC or 24VDC at 150Ah or 200Ah (Jiang et al., 2005).



Fig. 3.2: 200Ah Solar Battery

3.1.7 Charge Controller

The electronic voltage regulator, also known as the charge controller, regulates how much current may enter and exit batteries. When the battery reaches optimal levels, it pauses charging and restarts when it falls below a certain threshold to ensure a full charge without overcharging. By lowering safety risks and guarding against overvoltage, this crucial component preserves battery performance and life. For this project, MPPT Charge Controller will be used.

3.1.7 AC Motor

When an electric motor uses alternating current to generate mechanical motion, it is known as an AC (Alternating Current) motor. Its efficiency, robustness, and capacity to operate at different speeds with the aid of a controller make it a popular choice. The main propulsion mechanism in this solar-powered tricycle project is the AC motor. A battery pack stores the

energy collected from the solar panels, and an inverter uses the battery's DC (Direct Current) to change it into AC so that the motor can use it. Smooth acceleration, speed control, and economical energy use are made possible by a motor controller, which controls the power delivered to the AC motor. The motor is mounted on the rear axle, ensuring direct transmission of power to the wheels, reducing mechanical losses, and providing a sustainable, eco-friendly mode of transportation.

3.1.8 Braking System (Speed Controller).

The speed controller is essential for managing the tricycle's speed and functions as an electronic brake utilizing regenerative braking technology. This technique enables the motor to decrease the vehicle's speed while transforming kinetic energy into electrical energy, which is subsequently stored in the battery for later use.

In this project involving a solar-powered tricycle, the motor controller oversees the power supply to the AC motor, facilitating smooth transitions during acceleration and deceleration. When braking occurs, the controller diminishes the power to the motor, enabling it to function as a generator that changes surplus mechanical energy into electrical energy, rather than allowing it to dissipate as heat. This process not only boosts energy efficiency but also minimizes the degradation of standard mechanical brake parts, prolonging their service life.

Incorporating the speed controller into the braking system enhances safety, optimizes energy use, and improves ride comfort, thus increasing the tricycle's effectiveness and its sustainability for the environment.

3.1.9 Wheels

The wheels are used to enable the movement of the vehicle by transferring the rotational force from the motor to the ground. For stability, traction, and effective mobility, the solar-powered tricycle's wheels are crucial. The tricycle's two back wheels provide support and propulsion,

while the single front wheel serves as steering. Durability is ensured by lightweight steel or aluminium rims, while pneumatic tires absorb shocks and offer a smooth ride. The rear wheels receive torque from the AC motor through the gear system that is directly connected to the shaft connecting the rear wheels

3.1.10 Cable Wires

A cable wire is a type of solar wire that consists of multiple insulated wires. The electrical channels that link the solar panels, battery, motor, controller, and inverter are made possible by cable lines, which are essential to the solar-powered tricycle. High-grade, insulated copper wires are utilised to reduce energy loss, avoid overheating, and guarantee effective power transfer.

Electricity is distributed by the wires in the project from the solar panels to the battery for storage, and then to the motor via the controller and inverter. To ensure the tricycle operates smoothly, proper cable management is used to lower resistance, increase safety, and boost the electrical system's overall performance.

3.1.11 Mild Steel

This Mild steel, a low-carbon steel, is a great material for structural applications because of its strength, durability, and affordability. The frame construction is the main application for it in the solar-powered tricycle project; it offers a strong yet lightweight framework to support the engine, battery, rider, and other parts. Due to its high tensile strength, ease of welding, and resilience to mechanical stress, mild steel is the material of choice. By guaranteeing stability, balance, and load distribution, the frame makes it possible for the tricycle to endure a range of road conditions without losing its structural soundness. It also ensures long-term performance and durability by acting as a stable mounting base for the wheels, motor, and solar panels.



Fig. 3.3: Mild steel

3.1.12 Metal Sheet

The solar-powered tricycle's floor is made of metal sheet, which gives the rider and other parts a sturdy, long-lasting, and stable surface. Because mild steel and aluminium sheet are lightweight, corrosion-resistant, and have a good load-bearing capability, they are chosen. The project's metal sheet is firmly fastened to the tricycle's frame by welding or bolting, providing a stable platform that bears the weight of the rider and shields the electrical components underneath. To improve grip, reduce slippage, and increase safety while operating, the surface may be textured or coated. The tricycle's durability and structural integrity are improved by this flooring design.



Fig. 3.4: Pan

3.1.13 Electrode

A conductor that permits electricity to enter or exit a medium, such a battery or motor circuit, is called an electrode. Electrodes, specifically in the battery, solar panel connections, and motor drive system, are essential to the electrical system of this solar-powered tricycle project. Electrodes in the battery pack allow electrons to flow from the anode to the cathode, allowing for the storage and release of energy. The charge controller and battery receive the electricity produced by the solar panels through electrodes. Electrodes also contribute to the smooth operation of the motor circuit by effectively transferring power from the inverter to the AC motor.

3.1.14 Angle Bars

A structural element composed of metal (usually steel or aluminium) with an L-shaped cross-section is called an angle bar, sometimes referred to as an L-bar or angle iron. Because of its strength, durability, and effective load-supporting capacity, it is frequently utilised in fabrication and construction. The frame construction of this solar-powered tricycle project uses angle bars, which offer a sturdy and lightweight structure to withstand the weight of the motor, battery, rider, and other parts. The L-shaped design improves stability and load distribution by increasing rigidity while maintaining the frame's lightweight. Angle bars also support the solar panel frame during mounting, guaranteeing a solid and movable position for optimal exposure to sunlight.



Fig. 3.5: Angle Bars

3.1.15 Shock Absorbers

A shock absorber is a mechanical device that reduces vibrations and absorbs shocks from uneven roads to make riding more stable and comfortable. Impacts' kinetic energy is transformed into heat, which is subsequently released using compressed gas or hydraulic fluid. The suspension system of this solar-powered tricycle prototype has shock absorbers, namely at the front fork and rear wheels. In addition to lowering frame stress and protecting delicate parts like the battery, engine, and solar panels from severe vibrations, their functions include improving rider comfort. By improving stability and ride quality, the shock absorbers contribute to the durability and efficiency of the tricycle, making it suitable for various terrains.

3.1.18. Gears.

The gear transmit torque to the wheels from the shaft through the torque. Three gears were used to design the forward mechanism while four gears were used to design the reverse mechanism

For the Forward mechanism (made-up of three gear);

AC Motor (Driving Gear - Large Gear): This gear is directly connected to the motor and starts the motion. since it rotates clockwise (CW), the next gear (intermediate gear) it meshes with will rotate counterclockwise (CCW). Then the next gear (the gear connected to the diving shaft) meshed with it rotates clockwise (CW).

For the Reverse mechanism (made-up of four gear);

AC Motor (Driving Gear - Large Gear): This gear is directly connected to the motor and starts the motion, It has two intermediate gear between it and the gear connected to the shaft. since it rotates clockwise (CW), the next gear (1st intermediate gear) it meshes with will rotate counterclockwise (CCW). Then the second intermediate gear will rotate clockwise (CW). Then

the next gear (the gear connected to the diving shaft) meshed with it rotates counterclockwise (CCW).

3.2 METHOD

The fabrication of the solar-powered tricycle involved several stages, from material selection to final assembly. Below is a step-by-step account of the process:

Design and Material Selection

- Detailed design diagrams and CAD models were produced to illustrate the structure and arrangement of the tricycle components.
- Chose robust yet light materials like mild steel for the frame, aluminium alloy for the rims, and polycrystalline solar panels for effective energy capture.

Frame Construction

- Cutting and Shaping: Steel pipes and sheets were precisely measured, sawed, and formed in accordance with the design criteria.
- Welding and Assembly: The various components of the frame were welded together to create a sturdy tricycle framework, ensuring both stability and resilience.
- Grinding and Smoothing: Weld joints were polished and smoothed out to eliminate any rough edges and enhance the finish of the frame.

Mounting the Wheels and Suspension

- The front and rear wheels were affixed using suitable axles, bearings, and support brackets.
- A rear shock absorber system was installed to improve ride stability and comfort.

Installation of the Solar Panel and Battery

- A support structure for the solar panel was constructed and placed on the tricycle's roof to maximize sunlight access.
- The battery pack was safely installed in a compartment under the seat, ensuring balanced weight distribution.

AC Motor and Transmission System Integration

- The AC motor was positioned on the rear axle, allowing for direct or chain-driven movement.
- A motor controller along with an inverter was installed to manage the power supply and change DC from the battery into AC for motor use.

Electrical Wiring and Circuit Connections

- The solar panel, battery, motor, charge controller, and inverter were interconnected to facilitate effective power distribution.
- Safety features including fuses and circuit breakers were included to avert electrical issues.

Testing and Final Adjustments

- Initial testing was carried out to verify motor operations, battery performance, and solar charging ability.
- Wheel alignment, suspension firmness, and motor functioning were fine-tuned for peak efficiency.
- Conducted road tests to assess stability, energy use, and overall functionality.

Finishing and Painting

- The frame was treated with anti-corrosive paint and finished with protective enamel to ensure longevity.

- Labels, indicators, and safety reflectors were included for better visibility and visual appeal.

3.2.1. Design Factors

This pertains to certain traits that impact the configuration of the machine or possibly its various parts. Nevertheless, among the many elements that influenced the design, only a select few emerged as the primary contributors, while the less significant ones were overlooked due to their minimal or negligible influence on the design. These traits or characteristics include;

- a. Weight of the materials.
- b. Strength of the materials.
- c. Overall weight of the tricycle in order to achieve its portability and to aid the movement of the tricycle.
- d. Ease of maintenance.
- e. Resistance to corrosion.
- f. Cost and Affordability.
- g. Availability of materials.

3.2.2. Mechanical Fabrication Process

The process of mechanical fabrication includes two primary methods: welding and mechanical joining techniques.

In constructing a solar-powered tricycle, welding and mechanical joining are crucial since these methods are employed to connect different parts and materials, forming the vehicle's frame, structure, and additional assemblies. Prior to the fabrication stage, an in-depth examination of various welding and mechanical joining methods will be conducted below to identify the most appropriate option for the project.

3.2.2.1. Welding

Welding is a manufacturing methodology that involves the fusion of metallic parts through the application of heat, pressure, or a combination of both, resulting in a robust and lasting connection. This technique is frequently employed in building infrastructures, fabricating vehicles, and assembling machinery thanks to its reliability and resilience. Additionally, welding is vital for fastening the motor enclosure and brackets, which aids in maintaining correct alignment and load distribution. The integrity of the welds significantly impacts the tricycle's overall strength, dependability, and durability. For this project, Electric Arc Welding Technique was used. Electric Arc Welding is a welding process that uses an electric arc between an electrode and the base material to melt and join the materials together. Arc welding is commonly used in the fabrication of the tricycle's frame, using techniques such as shielded metal arc welding (SMAW) or gas metal arc welding (GMAW).

3.2.2.1.1. Welding Considerations

- i. **Material Selection:** The welding method chosen hinges on the types of materials used in creating the tricycle. Various materials necessitate distinct welding techniques to form robust and dependable connections. **Joint Design:** The configuration of the welded joints plays a vital role in the overall robustness and longevity of the tricycle's framework and associated parts. Effective joint design guarantees that the welds are evenly distributed and can endure the forces and pressures faced by the tricycle during operation.
- ii. **Weld Quality:** The integrity of the welds is essential for the tricycle's safety and functionality. Adhering to appropriate welding methods and practices is necessary to guarantee that the welds are durable, consistent, and devoid of imperfections. Techniques such as non-destructive testing (NDT) may be applied to assess the weld quality and detect any possible problems.

3.2.2.2. Mechanical Joining Processes

i. Bolting: Fastening with Bolts

Bolts along with nuts function to connect parts that can be separated, like a solar panel support, a battery shell, and a motor casing.

This technique facilitates straightforward component replacement, adjustment, or servicing without risking damage to the overall structure.

ii. Use of Rivets

Rivets are employed in places where a solid, enduring connection is essential, such as in reinforcing metal frames and attaching panels.

This technique results in a lightweight union that is resistant to vibrations.

iii. Screw and Nut Fasteners

Screws are utilized to hold electrical boxes, mounts for control panels, and seats in place.

They provide rapid assembly and disassembly, making it easy to access for repairs and alterations.

iv. Press-Fit Technique

This technique is applied to securely attach bearings, bushings, and wheel hubs onto shafts without using adhesives or welding methods.

It guarantees a snug fit and minimizes movement when subjected to operational stress.

3.2.2.2.1. Mechanical joining considerations:

i. Selection of Fasteners: The type of fasteners you choose is influenced by the materials involved, the forces and pressures the joint will encounter, and how much adjustability or ease of disassembly you want. Design of the Joint: The configuration of the mechanical joint plays

a vital role in its durability and dependability. A well-designed joint guarantees that the fasteners are evenly distributed and are capable of handling the loads and pressures faced by the tricycle during operation.

ii. Installation of Fasteners: Correctly installing the fasteners is crucial for maintaining the joint's durability and dependability. This requires the use of appropriate tools and torque specifications, the application of thread-locking adhesives when necessary, and adherence to the manufacturer's guidelines for installation methods.

iii. Lubrication of Fasteners: Some fasteners may need lubrication to avert rust, minimize friction during installation, and ensure accurate torque and tension. The lubricant's type is determined by the materials and surrounding conditions, and it must be suitable for both the fastener and the joint materials.

3.2.3. Design

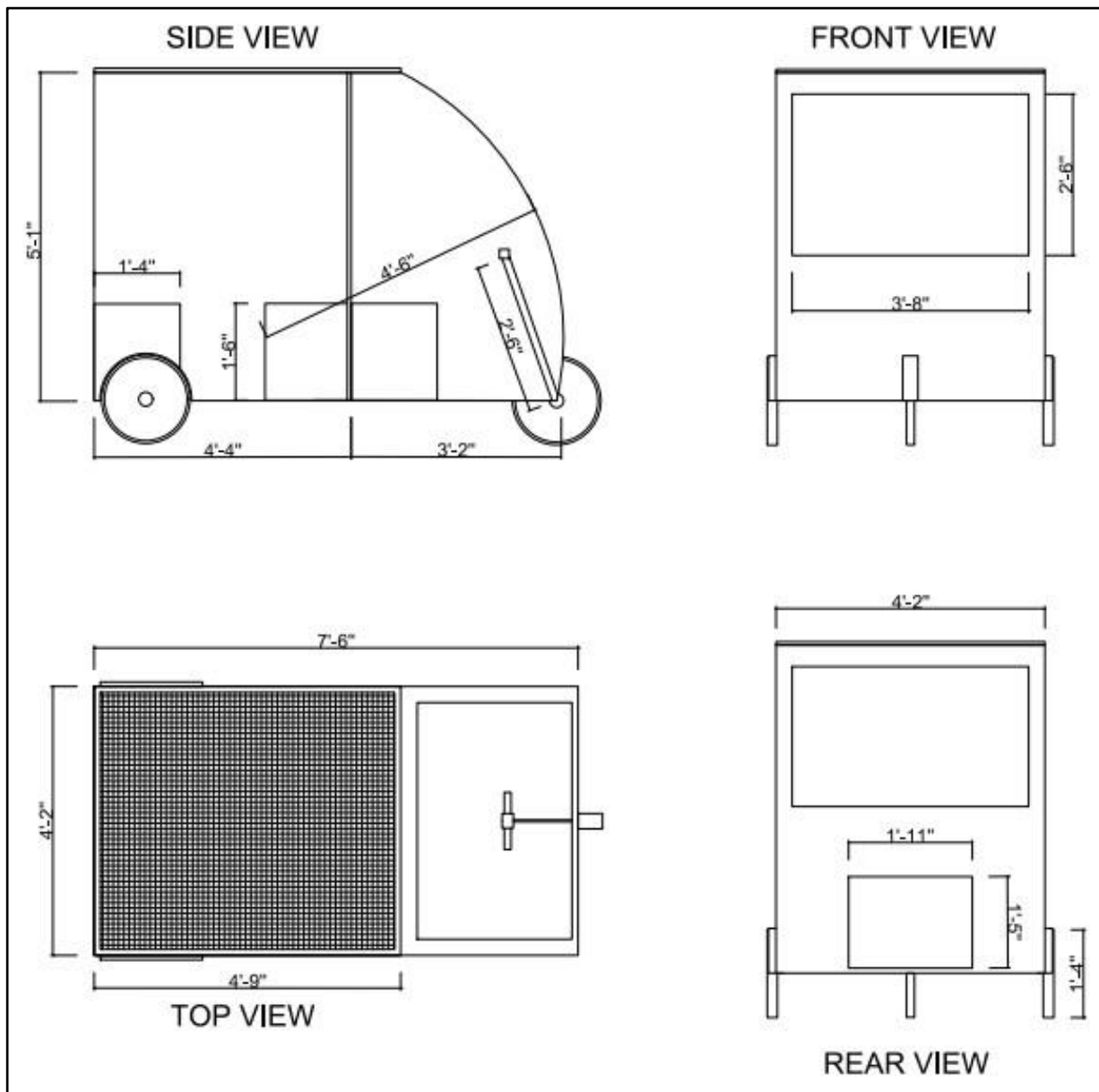


Fig. 3.6: Design of the Tricycle showing all views and Dimensions (all dimensions are in ft and inches)

3.2.3.1 Working Principle

The tricycle operates on a 24v deep cycle batteries connected in series. The batteries will be charged by a solar panel through a 60A controller whose function is the regulation of incoming energy to avoid overcharging with the aim of prolonging the life of these batteries.

The electrical energy in the batteries come through to the 2HP – 1492W AC motor via an inverter, which is what the motor requires.

A speed controller controls the \ac motor by changing the voltage supply, thus controlling the tricycle's speed.

It sits centrally between the rear wheels are the top of the chassis. The torque distribution to the wheels is effected by a central gear system mounted on the shaft of the rear axle for effective transmission.

Since it works in a continuous feedback system, the solar panels are always replenishing the batteries, even when the tricycle is not in motion, to ensure extended operation time with reduced dependence on charging sources.

3.2.3.2 Design Calculation

a. Change in voltage cause change in speed for solar powered tricycle.

24v – 20km/h, 12v – 10km/h, 6v – 5km/h, 3v – 2.5km/h

b. Calculation for AC Motor

How much power do we need in watts?

To determine the power rating of a single-phase AC motor for your electric tricycle, we need to consider several factors, including total weight, desired speed, terrain, and rolling resistance.

Let's break it down:

1. Total Weight Calculation

- Dead load (tricycle and components): 240 kg
- Passenger load (assuming 3 people, 70 kg each): $3 \times 70 = 210$ kg
- Total weight: $240 + 210 = 450$ kg

2. Forces Acting on the Tricycle

The total power required depends on the forces that the motor must overcome:

1. Rolling Resistance (F_r):

$$F_r = C_r \times M \times g$$

where:

C_r = rolling resistance coefficient (for rubber tires on asphalt, ~ 0.01)

M = total mass = 450kg

g = gravitational acceleration = 9.81 m/s²

$$F_r = 0.01 \times 450 \times 9.81 = 44.145\text{N}$$

2. Aerodynamic Drag (F_d):

$$F_d = 1/2 C_d A \rho v^2$$

where:

C_d = drag coefficient (~ 0.8 for a tricycle)

A = frontal area (~ 1 m²)

ρ = air density (~ 1.225 kg/m³)

v = velocity (assume 30 km/h = 8.33 m/s)

$$F_d = 1/2 \times 0.8 \times 1 \times 1.225 \times (8.33)^2$$

$$F_d = 34 \text{ N}$$

3. Grade Resistance (F_g) (for inclines, assume 5° slope:

$$F_g = M g \times \sin\theta$$

where $\theta = 5^\circ$ slope

$$F_g = 450 \times 9.81 \times \sin(5^\circ) = 44145 \times 0.087 = 38.406\text{N}$$

3. Total Force and Power Requirement

Total force required:

$$F_{\text{total}} = F_r + F_d + F_g = 44.145 + 34 + 38.406 = 116.551\text{N}$$

Power required at the wheels:

$$P = F_{\text{total}} \times v$$

$$P = 116.551 \times 8.33 = 970.87\text{W}$$

Considering efficiency losses in transmission (85% efficiency), the motor power should be:

$$P_{\text{motor}} = 970.87 \div 0.85 = 1142.2\text{W} = 1.1\text{kW}$$

4. Final Recommendation

A 1.2 - 1.5 kW (1.5 - 2 HP) single-phase AC motor should be sufficient to power the tricycle under normal conditions, ensuring enough margin for inclines and variations in load. If you expect steeper slopes or higher speeds, a 2 kW motor would be a safer choice.

Thus a 24V 2HP single phase AC motor would be efficient for the Tricycle.

c. Calculation for Battery System

1. Calculate total battery energy capacity

Battery capacity in watts-hours (Wh) is given by:

$$E = V \times Ah$$

Where:

$$V = 24V$$

$$Ah = 200Ah$$

$$E = 24V \times 200Ah = 4800Wh = 4.8KWh$$

2. Determine power consumption of the motor

The 2HP (1.5KW) AC motor has an efficiency of about 85%, meaning the actual power drawn from the battery is;

$$P_{input} = P_{motor} / \eta = 1.5KW / 0.85 = 1.765KW$$

3. Estimate running time

The running time t in hours is given by:

$$t = \frac{\text{Battery Energy}}{\text{Power Consumption}}$$

$$t = \frac{4.8KWh}{1.765kW} = 2.72\text{hours (2hrs 43mins)}$$

Conclusion; On a flat terrain, the tricycle can run for approximately 2 hours 43 minutes before the depletion of the battery.

But if the tricycle runs at lower power it could last longer. And when running on an incline plane its efficiency drops.

[Tak Kenjo. Oxford University Press, 1991 3rd edition.]

d. Calculation for whole complete solar powered tricycle

Determine the torque (force) that must be generated at each wheel in order to meet the functional requirement.

Mass of wheel = 6.804 kg, Acceleration = 0.9144 m/s^2 , Torque = Newton/meters

$$F = MA$$

$$\text{Force} = \text{Mass (kg)} \times \text{Acceleration (m/s}^2\text{)}$$

$$\text{Force} = 6.804 \text{ (kg)} \times 0.99144 \text{ (m/s}^2\text{)}$$

$$\text{Force (total)} = 5.8\text{N}$$

The Total force required to meet the Functional Requirement is 5.8N. However, the solar powered tricycle has the motor and two wheels at rear axle, the front wheel is pushed. Therefore each motor/wheel combination needs only supply half the required force or 2.9N.

$$\text{Force Wheel} = 2.9\text{N [Tak Kenjo. Oxford University Press, 1991 3}^{\text{rd}}\text{edition.]}$$

e. Specification of the Proposed Tricycle Components

So according to the engineering design calculations the required components:

- 3 Solar panel: 450W

4 Single Phase AC motor: 24 Volt, Power rating is 1142.2W, 300 rpm

5 2 Battery of 12 Volt; 24V 200Ah.

The block diagram of the solar power system used in the project gives the overall working structure of the system. Initially the solar panel is placed on the top of the tricycle, which converts the solar energy to electrical energy, is connected to the battery in order to charge it with the help of a charge controller, the charge controller converts the fluctuating/pulsating flow of electric charge into constant flow of electric charge which can be supplied to the battery to charge it.

Now, the battery supplies the required amount of power to the AC motor, which is connected to the axle of the wheel. A speed controller is provided to control or maintain the speed of the tricycle.

f. Speed of tricycle calculation

Given data: Power of tricycle = W, Mass of tricycle and persons = 450kg

$$g=9.81\text{m/s}^2$$

$$\text{speed} = V = \sqrt{\frac{2 \times P}{M}}$$

$$V = \sqrt{\frac{2 \times 1142.2}{450}}$$

$$V = 2.253\text{m/s} = 8.1\text{km/h}$$

The solar powered tricycle maximum speed should not exceed the above calculated.

vii. Gear System

The gear transmit torque to the wheels from the shaft through the torque.

h. Bearing Design and Selection

The single row deep groove ball bearing was chosen because of its high load carrying capacity and suitability for high running speed. Considering the diameter of the shaft which is 25mm, a bearing of bore 25mm was then used for this calculation. The specific static load rating or capacity C_o (Arvid, 1945)

$$C_o = \frac{1}{5} \times k_o \times i \times z \cos \alpha D_w^2$$

Where:

C_o = Specific Static Load rating or Capacity = 10kN

K_o = Factor depending on the type of bearing = 12.3

D_w = Diameter of the ball

α = Nominal angle of contact = 0

i = Number of rows of ball in any one bearing = 1

z = Number of balls per row in the groove = 6

$$K_o = \frac{Q_{max}}{D_w^2}$$

Q_{max} = Maximum bearing load

And the above data (Budynas *et al.* 2008) the ball diameter can be calculated

$$D_w = \sqrt{\left(\frac{C_o \times 5}{K_o \times i \times z \cos \alpha} \right)}$$

$$\sqrt{\left(\frac{10 \times 10^3 \times 5}{12.3 \times 1 \times 6 \cos 0} \right)}$$

$$= \sqrt{677.5067751}$$

= 26.02896 mm

Then the maximum bearing load Q_{max} becomes:

$$K_o = \frac{Q_{max}}{Dw^2}$$

$$Q_{max} = K_o \times Dw^2$$

= 12.3×677.5067751

= 8333.33N

A bearing of 6206, which is of an inner diameter of 25mm and outer diameter of 55mm, then was chosen. The bearing number interpreted as 200 means a light bearing of bore that is inner diameter of $5 \times 5 = 25$ mm. Also, in the selection of this bearing, the radial load of which the bearing can carry was put into consideration. However, for the ball lubrication, grease is used at low and medium speed when the temperature is not over 20°C while oil is used at higher speed. Hence, for this design, grease is regarded as the most satisfactory lubricant.

3.2.4. Analysis of the Shaft Design

The shaft can be designed for strength, rigidity and stiffness as considered for most shaft members. If these are to be considered as necessitated in our work, one or all of the followings has to be put into consideration:

1. If the shaft is subjected to a twisting moment or torque only
2. If it is subjected to bending moment only
3. If it is subjected to fluctuating loads
4. If it is subjected to combined twisting and bending moments
5. If it is subjected to axial loads in addition to combined torsion and bending loads.

In designing shaft on the basis of strength, shaft subjected to axial loads in addition to combine torsion and bending loads was taken into consideration (Khurmi R.S *et al.* 2006). Consideration was given to the axial load (F) which comprises the plate that was being attached to the shaft, likewise the weight of the chicken to be de-feathered.

Since mild steel is used for the shaft, maximum shear stress theory is used for the design of shaft diameter and it is stated below according to J.K. Gupter (2008)

$$D^3 = \frac{16}{\pi S_s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

Where;

K_b = combined shock and fatigue factor applied to bending moment;

K_t = combined shock and fatigue factor applied to torsional moment;

M_b = Bending Moment (Nm)

M_t = Torsional Moment (Nm)

S_s = Allowable shear stress

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Fabrication and Assembly

After the completion of the fabrication of the solar powered tricycle, Re-adjustment process was taken into consideration due to the numerous design defect done to the chassis and frame of the tricycle. Adjustments were done in the following areas, the reduction of the height of the chassis above the ground, the placement of shock absorber to withstand impact.

The ground clearance of the chassis was reduced from 22 inches to 11-inch front wheel and 10-inch rear wheel as shown in Figures 4(e) and 4(f). This modification was implemented to enhance the tricycle's stability, handling, aerodynamics, and overall efficiency while maintaining sufficient ground clearance for smooth operation.

The lowered chassis hugely improves the center of gravity, further making the tricycle stable and resistant to tippiness while navigating turns or carrying loads. The reduced height improves the aerodynamics, minimizes air resistance, and optimizes energy. By lowering the chassis, maneuverability is greatly improved, hence making management easier and smoother in city conditions.

Other benefits of the low chassis height include ease of access, as it allows easy mounting and dismounting from the tricycle, and facilitates convenience for passengers and loading cargo. With reduced height, there will be lesser energy required to accelerate, thus resulting in increased efficiency of motors and prolonging the life of a battery.

Despite the reduction in height, careful consideration was given to ensuring that the tricycle retains adequate ground clearance, allowing it to traverse uneven surfaces without compromising performance or structural integrity.

Putting a system in place to withstand impact; Our team successfully fabricated a metal frame designed to provide a secure and stable mounting structure for the suspension system's shock absorbers. The frame was engineered to ensure proper alignment, structural integrity, and durability, preventing unwanted movement and ensuring the shock absorbers perform efficiently under various operating conditions.

High-strength steel was chosen for its excellent mechanical properties, including high tensile strength, impact resistance, and durability. This material ensures the frame can withstand the forces exerted by the suspension system while maintaining its structural integrity over time.

The fabrication process began with precise cutting of metal components using mechanical saws to achieve accurate dimensions. The cut components were then bent and shaped as required to fit the design specifications. Welding was performed using electrical arc welding to join the structural components, ensuring strong and reliable connections. To enhance durability and resistance to environmental factors such as corrosion, the frame underwent surface treatments.

Once fabricated, the frame underwent a thorough inspection to verify dimensional accuracy, weld integrity, and overall quality. Precision-drilled mounting points were incorporated into the design to facilitate proper attachment of the shock absorbers. High-strength fasteners, such as Grade 8 bolts and lock nuts, were used to ensure a firm, vibration-resistant connection. Torque specifications were carefully followed during installation to prevent over-tightening or loosening due to dynamic forces encountered during operation.

The completed metal frame provides a robust and reliable support system for the suspension, ensuring that the shock absorbers remain securely in place while effectively absorbing and

distributing forces. This fabrication enhances the overall performance, longevity, and safety of the suspension system.



(a)



(b)



(c)



(d)



(e)



(f)

Fig. 4.1(a-f): Fabrication Processes

4.2. Electrical Installation

The electrical installation of the solar-powered tricycle involved integrating key components, including the solar panel, charge controller, battery, AC motor, and wiring system, to ensure efficient power distribution and functionality.

The process began with the mounting of the solar panel in an optimal position to maximize sunlight absorption. The charge controller was then connected to regulate power flow between the solar panel and battery, preventing overcharging and deep discharging. A deep-cycle battery was installed to store the generated energy, ensuring a stable power supply for continuous operation.

Next, the AC motor and motor controller were wired to the battery, enabling smooth and controlled power transmission. Proper cable management and insulation were implemented to minimize power losses, prevent short circuits, and enhance safety. Electrical components were securely fastened, and connections were tested to confirm functionality.

Once the installation was complete, the system underwent a series of tests to ensure efficient energy conversion, proper motor response, and overall system reliability. Adjustments were made where necessary to optimize performance, ensuring the tricycle operated safely and efficiently under real-world conditions.

4.3. Costing

This section is devoted to the estimation of the cost of developing a solar powered tricycle that will be fit for market and such cost include: material cost, labour cost, supervisory cost, assembly cost, transportation cost, finishing cost, installation cost and miscellaneous.

The above cost can be divided into the following subsets:

- 1 Material costs
- 2 Procurement cost
- 3 Fabrication cost

4.3.1. Material Cost

A market survey was first carried out in order to determine the cost of material required for the development of a solar powered tricycle.

Table 4.2: Cost of Materials

S/N	DESCRIPTION	QTY	AMOUNT (N)
1	Angle Bar	2	25,000
2	2 and half inch round galvanized pipe	1	10,000
3	Gears	8	20,000
4	Shock Absorber	2	42,000
5	Pack of Electrodes	1	5,000
6	12v 200Ah Batteries	2	510,000
7	450watts Monocrystalline Solar Panel	1	120,000
8	AC Motor (2 HP)	1	120,000
9	Inverter (3000 Watts)	1	70,000
10	Speed Controller	1	80,000
11	Charge controller	1	30,000
12	Solar Cables (per yard)	3	6,000
13	Terminals for Batteries	2	4,000
14	Tires and Tubes	3	60,000
15	Rims	3	21,000
16	Cutting stone, Filling stone and Filler	1	20,000
TOTAL			1,143,000

4.3.2. Fabrication Cost

The fabrication cost is the cost of the process such as supervision, cutting, machining, welding and assembly. Table 4.3 gives an estimate of the various cost incurred during the fabrication process

Table 4.3: Fabrication Cost

S/N	OPERATION	COST (N)
1	Supervision	30,000
2	Cutting	20,000
3	Welding	30,000
4	Assembly	20,000
TOTAL		100,000

4.3.3. Procurement Cost

Miscellaneous expenditure and other services such as transportation cost, waybill etc. Also, other costs arising from redesigning and fabrication is also included in the procurement costs.

The procurement cost is listed in Table 4.4.

Table 4.4: Procurement Cost

S/N	DESCRIPTION	COST (N)
1	Transportation	20,000
2	Design and Consultancy	20,000
3	Miscellaneous	10,000
TOTAL		50,000

The Table 4.5 shows the total production cost of the solar powered tricycle

Table 4.5: Production Cost

S/N	DESCRIPTION	COST (N)
1	Material Cost	1,143,000
2	Fabrication Cost	100,000
3	Procurement Cost	50,000
TOTAL		1,293,000

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The solar-powered tricycle initiative exemplifies the capabilities of solar energy as a renewable option for eco-friendly transportation. This endeavor intended to tackle the challenges of environmental degradation linked to carbon emissions from vehicles, which rank among the primary contributors to greenhouse gas emissions, exacerbating the greenhouse effect and fueling climate change. By developing a tricycle powered by solar energy, the initiative sought to showcase a cleaner, more efficient form of transport that could diminish carbon output and encourage a more sustainable future.

The creation and engineering of this solar-driven tricycle illustrate the practicality of environmentally friendly and sustainable travel methods. By harnessing solar power, incorporating an AC motor, and utilizing a thoughtfully designed frame, the tricycle provides a dependable and energy-efficient substitute for traditional fuel-based vehicles.

This initiative highlights essential engineering concepts such as mechanical design, electrical integration, and energy management to guarantee peak performance. Implementing solar panels, battery storage systems, and a high-performing drive mechanism allows for uninterrupted operation while keeping environmental effects to a minimum. Furthermore, the choice of wheels, welding methods, and mechanical assembly techniques enhances both the strength and functional capabilities of the tricycle.

The project commenced with the design phase, which included creating multiple design ideas and assessing them to identify the most effective option. The chosen design concept was crafted into a technical schematic for the prototype. Following this, the manufacturing phase took place, involving the assembly of the tricycle's frame and structure, installation of mechanical parts, and incorporation of the solar power system. The solar panel was installed on the top of

the tricycle, connected to the battery and electrical system, and managed through a solar charge controller.

The outcome was a fully operational prototype of a solar-powered tricycle that showcased the potential of this innovation to foster sustainable and eco-friendly transportation. This initiative underscored the necessity of lowering carbon emissions and advancing the use of renewable energy within the transportation industry. By utilizing solar energy, the solar-powered tricycle holds the promise of providing a cleaner, more efficient transport method while decreasing carbon footprints and safeguarding the planet.

The application of this project in agriculture offers a viable alternative to the sector's demand for more sustainable transport solutions, particularly benefiting smallholder farmers who depend on manual or fossil-fuel-driven transport. The solar-powered tricycle could facilitate numerous farming activities, including moving crops, fertilizers, and other necessary supplies, as well as assisting in irrigation and harvesting tasks. The solar PV system on the tricycle could supply a dependable and eco-friendly energy source, particularly beneficial in isolated and off-grid regions, thus decreasing dependency on fossil fuels and minimizing carbon emissions.

Moreover, the ability of the solar-powered tricycle to enhance the living standards of smallholder farmers is significant. Low operating expenses and heightened efficiency could boost farmer productivity and profitability. Additionally, the tricycle's straightforward operation and easy maintenance make it attainable for farmers with limited technical expertise and resources.

In summary, the solar-powered tricycle initiative has illustrated the promise of solar energy as a renewable resource for sustainable transport. Continued research and development in solar-powered transport technologies could result in considerable reductions in carbon emissions and marked enhancements in sustainable agricultural practices, farmer incomes, and environmental health. This project also emphasizes the critical need to tackle environmental challenges

stemming from the transportation sector and to support sustainable initiatives that lessen their impact.

5.2. Recommendations

Additional investigation and enhancement of the solar-powered tricycle prototype initiative may result in significant progress in both sustainable transportation and renewable energy solutions. Below are several suggestions for further exploration of the project:

i. Enhance solar photovoltaic system efficiency: The incorporation of a solar photovoltaic system into the tricycle framework was a pivotal element of the initiative. Nonetheless, additional research could focus on optimizing the efficiency of the system, potentially by refining the design of the solar PV panels and boosting battery capacity.

ii. Implement performance evaluations: Evaluating the performance of the solar-powered tricycle could yield essential insights into its functionalities and drawbacks. Assessments might include analyzing the tricycle's speed, the distance it covers, and the quantity of energy produced and stored by the solar PV system.

iii. Investigate alternative renewable energy sources: Although solar energy was utilized in this project, further investigation could be carried out to examine other renewable energy options like wind or hydropower for operating the tricycle. This could lead to a broader understanding of various renewable resources and their roles in sustainable transportation.

iv. Undertake a life cycle analysis: Performing a life cycle analysis of the solar-powered tricycle could shed light on its environmental consequences throughout its entire lifespan. This process could assist in pinpointing areas for enhancement and promoting the tricycle's overall sustainability.

v. Evaluate scalability and mass manufacturing: To increase the accessibility of the solar-powered tricycle to the wider public, it is important to consider scalability and mass production.

Further studies could investigate the practicality of mass-producing the tricycle and distributing it to a larger demographic.

In summary, ongoing research and innovation surrounding the solar-powered tricycle prototype could pave the way for progress in sustainable transport and renewable energy alternatives. These suggestions can serve as a foundational guide for future research and contribute to unlocking the complete potential of solar-powered transportation solutions.

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